FORECASTING PRECIPITATION OCCURRENCE FROM PROGNOSTIC CHARTS OF VERTICAL VELOCITY

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ABSTRACT

An empirical study is made of the relationship of precipitation occurrence to vertical velocity and dewpoint depression. Based on this work, a method of forecasting precipitation occurrence is developed. The method uses two predictors, the prognostic charts of 500-mb. vertical velocity made by the JNWP Unit with a thermotropic model, and the dewpoint depression. Tests of the method suggest it is widely applicable in the eastern United States.

1. INTRODUCTION

Although other investigations have been made and are continuing on the numerical solution of physical models to compute precipitation, it was interesting to note in a U. S. Navy [1] publication on numerical weather prediction that an empirical study of the relation of vertical motion to precipitation occurrence might be worth pursuing as an interim aid to forecasters. The Navy study included a graph showing precipitation occurrence as a function of two variables, the vertical velocity above a station integrated through a specified time interval, and the initial mean mixing ratio through a layer above the station. In the present study, this general approach is refined and extended to three stations, Albany, N. Y., Washington, D. C., and St. Louis, Mo. Different humidity variables have been explored, with a view to developing a practical technique for estimating the probability of occurrence of precipitation based on the Joint Numerical Weather Prediction (JNWP) Unit's prognostic vertical velocity and available humidity data.

2. DEVELOPMENT OF METHOD

The JNWP prognostic charts of vertical motion at 500 mb. from July 1956 through May 1957 were available. These prognostic charts were based on the thermotropic model [2] at the time this study was conducted. The total upward displacement in 24 hours, of the air moving past the station, was estimated by a graphical integration of vertical motion values from three successive charts 12 hours apart. For figure 1, an approximation of an "observed" vertical displacement was obtained by using the input chart at 1500 GMT, the 12-hour prognostic chart for the subsequent 0300 GMT, and the next day's input chart at 1500 GMT. This spans a 24-hour period with two input values and an intermediate 12-hour prognostic value, all read for Albany. The vertical motion was assumed to vary linearly from one chart to the next, negative values were taken to be zero, and the total upward displacement determined from the positive values. This, of course, is not the vertical displacement of a moving air parcel, but represents the net upward displacement within successive air parcels passing over the station. The unit of upward displacement in all illustrations is hundreds of meters and the scale is logarithmic above one hundred meters. On the average, larger vertical velocities were observed during the winter season and for this reason the figures 1, 2, and 4 are divided into two parts for representing winter and summer data separately.

The dewpoint depression in figure 1 is the average of values for the surface, 850 mb., and 700 mb., observed at Albany at 1500 GMT, the beginning of the 24-hour period. Days represented on the graphs include all days from July 1956 through May 1957. Measurable rain occurring during the 24-hour period is indicated as a cross, and no-rain or trace, as an open circle. The lines dividing the charts into regions A, B, and C were placed so as to achieve a maximum number of cases in the high probability and low probability groups. Notice that to have approximately the same number of cases for like regions, the regions were adjusted for larger displacements on the winter season chart.

3. TESTS OF METHOD

Next, tests of this technique were made on the three stations, Albany, Washington, and St. Louis, using JNWP prognostic vertical motion values for 12, 24, and 36 hours, in place of the "observed" vertical motion values used in deriving the graph. The local average (surface, 850-, and 700-mb.) dewpoint depression at 1500 GMT, the time of the input data for the numerical prognosis, and the concurrent average (surface, 850-, and 700-mb.) dewpoint depression at an upstream station were averaged

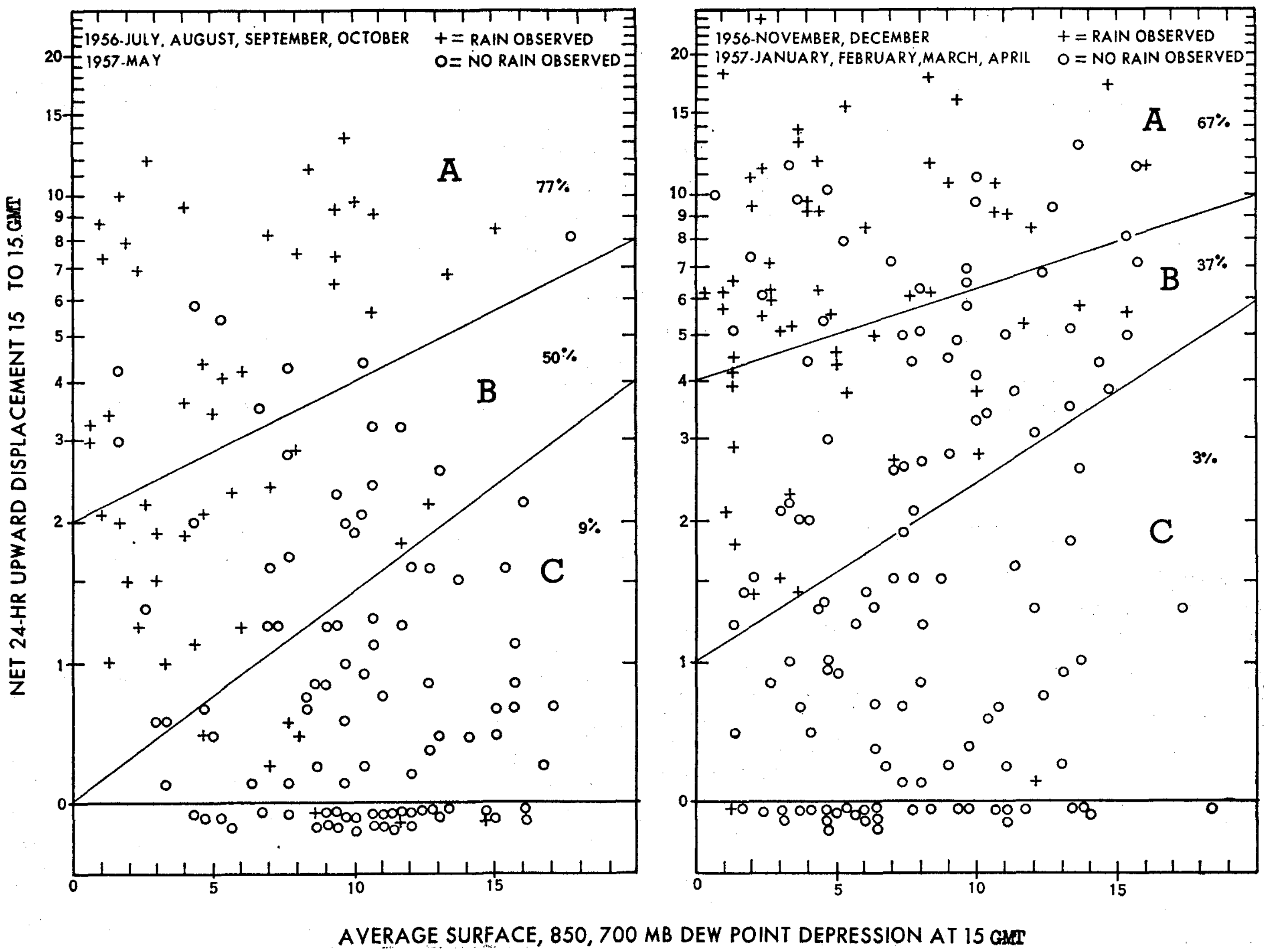


FIGURE 1.—Precipitation occurrence at Albany, N. Y. as a function of humidity and vertical motion. Dewpoint depression in ° C. measured at Albany at beginning of 24-hour period. Vertical displacement in hundreds of meters obtained from JNWP "observed" charts at beginning and end of period plus 12-hour prognostic chart for middle of period.

to obtain the abscissa. The upstream station was located from the observed 1500 GMT 700-mb. chart by tracing the appropriate contour upstream approximately 10 hours at the geostrophic wind speed and selecting the nearest radiosonde station. Figure 2 shows the forecast data for Albany, and figure 3 summarizes the results of forecasts for Washington and St. Louis. It should be emphasized that the boundary lines for areas A, B, and C developed in using Albany "observed" data in figure 1 were used on all subsequent graphs for Albany, Washington, and St. Louis. No significant improvement could be obtained by developing different relationships for Washington and St. Louis. The abscissa on the St. Louis charts was the average dewpoint depression of Columbia, Mo., only.

The results of using the "observed" vertical velocities are shown in the left hand columns of figure 3. Test results using prognostic vertical velocities are shown in the right hand columns. Precipitation was measured over a 24-hour period beginning at 1100 GMT for Washington and Albany and at 1000 GMT for St. Louis in order to extend the period of the forecast and to correspond more closely to the period covered by official forecasts. On a smaller sample of Washington data (July 1956–November 1956), a 9-hour lag of weather (precipitation and cloudiness) compared as well with the observed vertical motion as a 3-hour lag. Panofsky et al. [3] have remarked on this phenomenon that "vertical motion corresponds to a weather tendency."

Thus, for the period of July 1956 through May 1957, the prognostic vertical motions could have indicated for Albany a group of days for which the chance of rain was 63 percent, another group of 34 percent chance, and a group of 14 percent. As shown by figure 3, application of this prediction diagram to Washington, D. C., gave

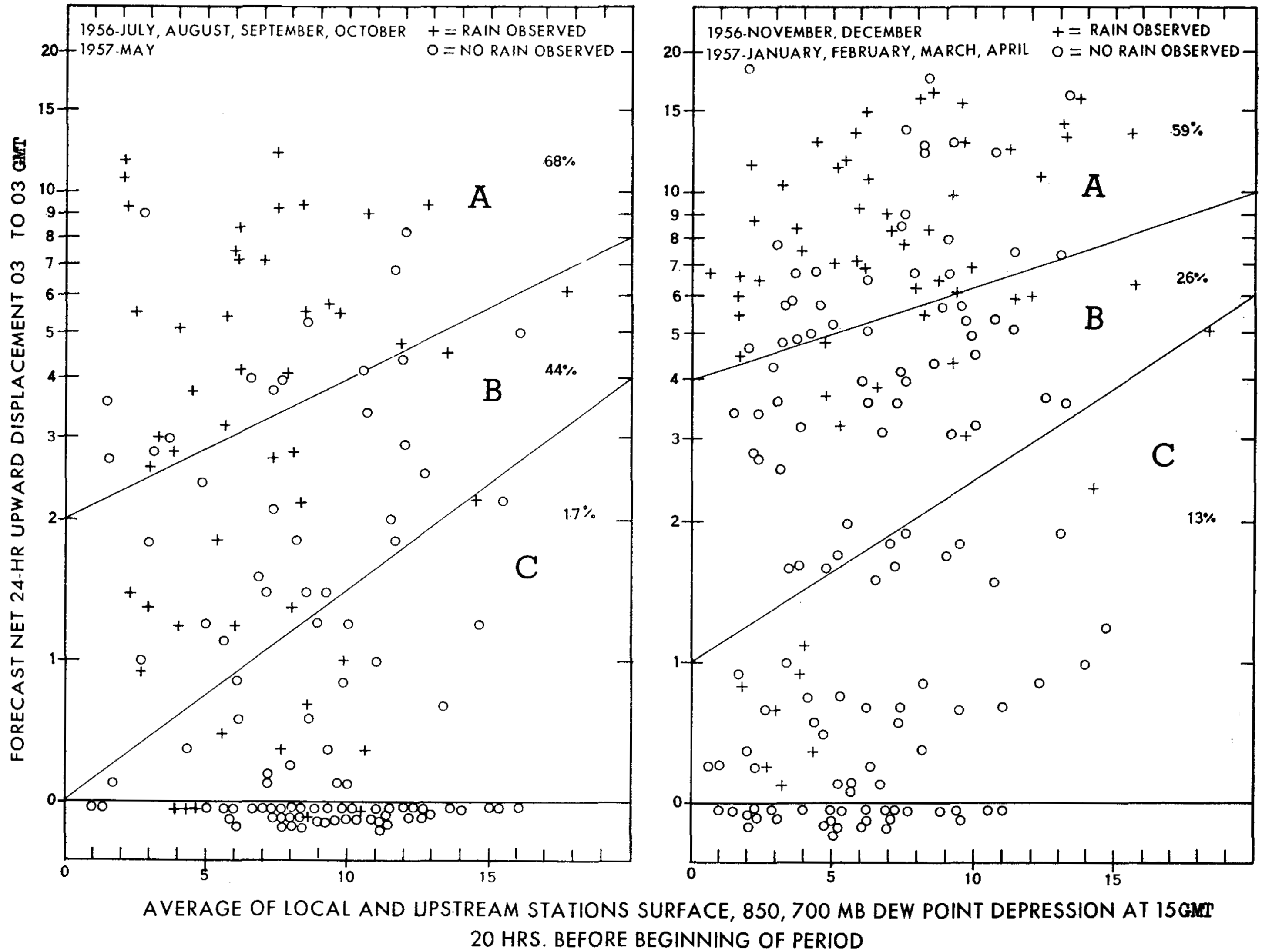
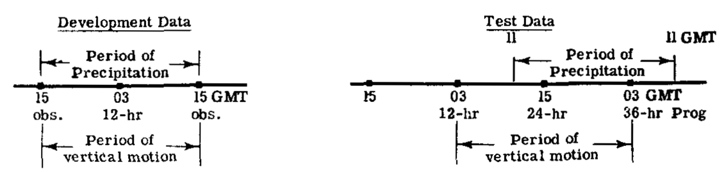


FIGURE 2.—Precipitation occurrence at Albany, N. Y. as a function of humidity and vertical motion. Dewpoint depression in °C. measured at Albany and an upstream station 20 hours before beginning of 24-hour precipitation period. Vertical displacement in hundreds of meters obtained from JNWP 12-hour, 24-hour, and 36-hour prognostic charts.

essentially the same results, and to St. Louis, Mo., strikingly similar results.

A test on precipitation occurrence by 12-hour periods was carried out for Albany. Figure 4 shows the test results. JNWP 12-hour and 24-hour prognostic vertical velocities were used to forecast precipitation occurrence for the period 20 to 32 hours in advance of the initial time, and 24-hour and 36-hour prognostic vertical velocities were used to forecast for the period 32 to 44 hours in advance. For the shorter lag, the three groups indicated 69 percent, 42 percent, and 16 percent probability of precipitation. For the longer lag, however, the precipitation frequencies in areas A and B were essentially the



Class	Total No. of cases	No. of Rain cases	% Rain	Total No. of cases	No. of Rain cases	% Rain
			ALBANY, N. Y.			
A	91	65	71	102	64	63
B	89	37	42	77	26	34
C	146	9	6	149	21	14
			WASHINGTON, D. C.			
A	84	59	70	106	67	63
B	92	32	35	88	31	35
C	150	16	11	134	20	15
			ST. LOUIS, MO.			
A	88	50	57	105	56	53
B	98	38	39	88	25	28
C	149	11	8	135	19	14

FIGURE 3.—Precipitation forecasts for Albany, N. Y., Washington, D. C., and St. Louis, Mo., based on an empirical relation of precipitation occurrence to vertical motion and moisture content. July 1956 through May 1957. See figure 1 or 2 for definitions of classes A, B, C.

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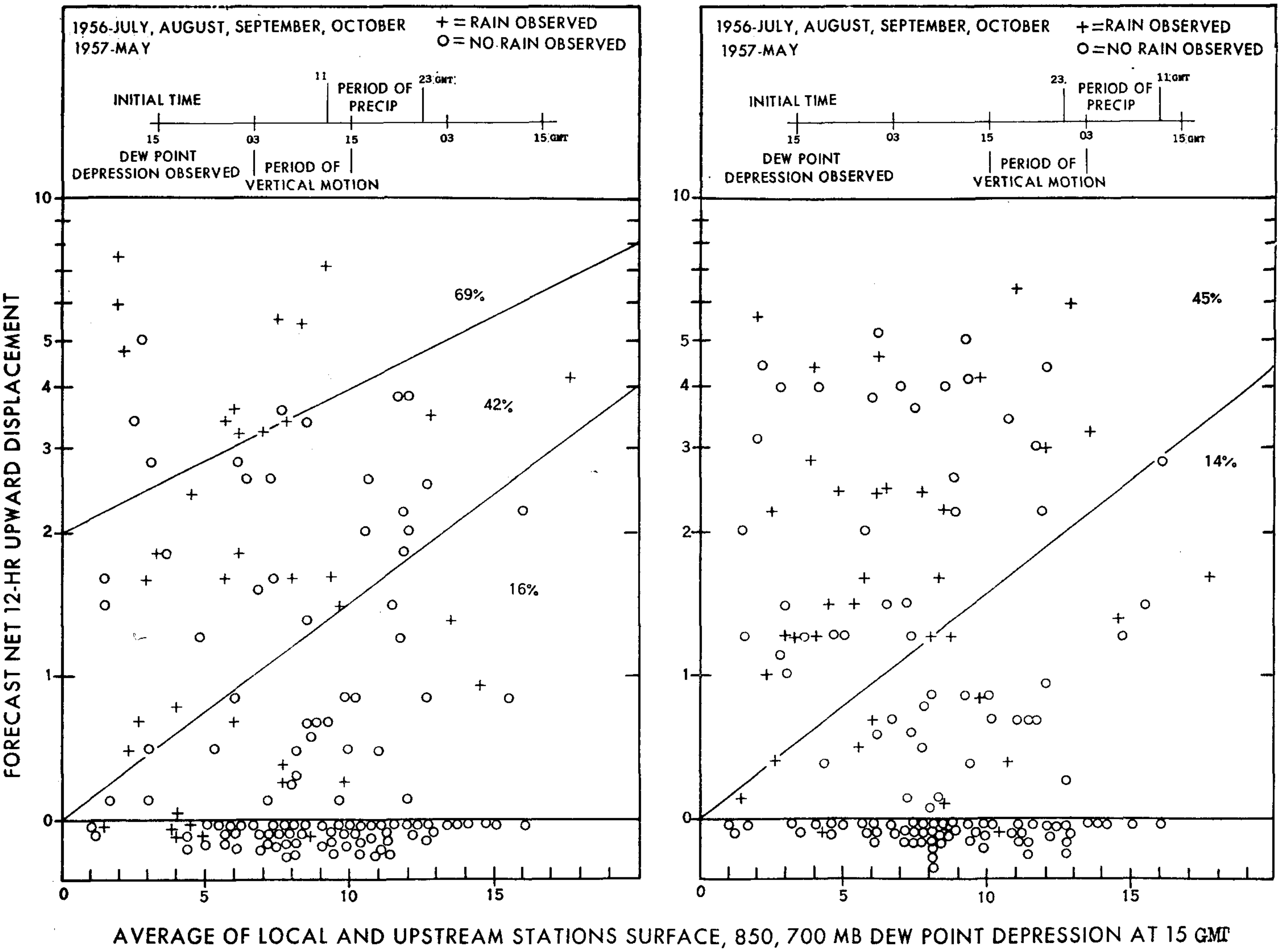

FIGURE 4.—Precipitation occurrence by 12-hour periods at Albany, N. Y. as a function of humidity and vertical motion. Time relationship of the variables and precipitation occurrence is shown in upper part of each section.

same, and the diagram indicates only a group of cases with 45 percent probability and a group with 14 percent.

These results cannot be used operationally until prognostic vertical motion charts are again issued routinely. In the meantime, however, prediction of the moisture variable could be improved. Experiments in this direction using rough extrapolation of "upstream" dewpoint depression suggested that a more detailed computation of moisture trajectory might further improve the forecasts. Such work has been reported by Lewis [4].

4. CONCLUSION

The almost identical results of applying this technique to Washington and Albany suggest that this same chart would be of value as an aid in forecasting precipitation for other stations along the eastern coastal area. Stations in different areas of the country with different climatology and orographic features would be likely to have different chances of rain for the same displacement areas. As concluded from results of the Albany, Washington, and St. Louis charts, an above normal chance of precipitation would be expected for any station when the positive vertical motion is forecast to remain above normal, and chances of precipitation are quite low when the vertical motion is forecast to remain very low or negative.

An improvement in the charts would be expected with an improved method of forecasting the moisture variable. In its present form, this technique is of little or no value for predicting the amount of precipitation. Further study is recommended to determine whether mixing ratio or total precipitable water as computed from Showalter's [5] template may be more useful moisture variables for quantitative forecasting. Further study will be necessary, also, as other prediction models are placed into operation by the JNWP Unit.

REFERENCES

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Weather Notes

LOWEST TEMPERATURE IN GREENLAND

In her excellent article on the lowest temperatures observed on earth Miss Stepanova [1] accepts −64.8° C. (−84.6° F.), recorded at two sites on the icecap, as the lowest temperature observed in Greenland. It would be reasonable to expect that this value might be exceeded in other parts of the icecap. And indeed, a lower temperature has been recorded at the British station "Northice" (78°04′ N., 38°29′ W., elevation 2,345 meters).

In looking over the radio-teletypewriter transmissions for Northice, early in 1954, we were surprised to note a temperature of −94° F. on January 9. In correspondence with the British Meteorological Office, we learned that this value was in error; the actual minimum recorded for that day was −86.8° F., which was nevertheless the lowest temperature as yet recorded in Greenland.[1]

[1] Ed. Note: In a personal communication, Miss Stepanova states that unfortunately the documentation [2] of this record low temperature in Greenland was not available to her when she compiled her report [1]. She is pleased that Mr. Quiroz has brought the record up to date in his note.

This occurrence was later documented by Hamilton and Rollitt [2]. Instrumental error is shown to have been small. Altogether, temperatures below −75° F. were recorded on 16 occasions in a period of 20 months (November 1952–June 1954), suggesting that values significantly lower than −86.8° F. might be expected over a longer period of time.—*Roderick S. Quiroz, U. S. Air Weather Service Climatic Center, Washington, D. C.*

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